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Effects of Synfuel Use

TRW Energy Systems Group
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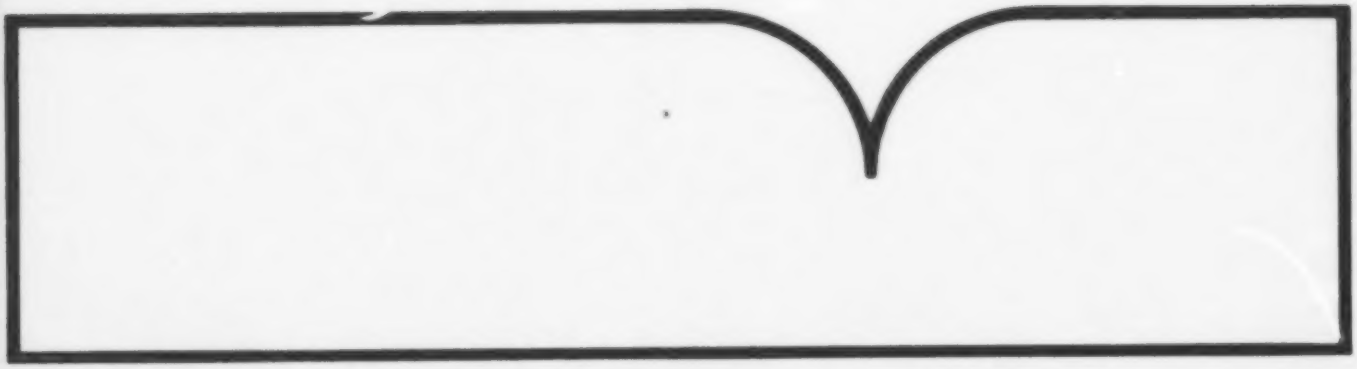

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16. ABSTRACT

This paper reviews environmental concerns relating to the distribution, handling, and end use of synfuel products likely to enter the marketplace by the year 2000, and assigns priority rankings to the products based on environmental concerns to aid EPA to focus its regulatory and research activities. Major products and by-products from oil shale, coal liquefaction, and coal gasification technologies are considered. Results indicate that: (1) significant quantities of synfuel products are expected to enter the marketplace during the next 20 years; (2) large-scale transportation, distribution, and end use of certain synfuel products can present significant threats to the environment and the public health; (3) based on gross characteristics, synfuel products appear to be similar to petroleum products, but detailed characterization data are not available with which to judge their relative safety; and (4) synfuel test and evaluation programs currently underway or planned provide excellent opportunities for collecting some of the required environmental data. Three likely scenarios for shale- and coal-based synfuel plant buildup are projected. The type and quantity of synfuel products and by-products likely to enter the market are identified and their regional market penetration is estimated. The environmental analysis consists of a review of available data on the physical, chemical, and health effects characteristics of synfuel products and environmental significance of their characteristics.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Assessments	Stationary Sources	14B
Coal	Synfuels	08G
Liquefaction	Synthetic Fuels	07D
Coal Gasification	Environmental Impacts	13H
Shale Oil		

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Because large quantities of products are expected to enter the market, process developers, regulators, and users are concerned with environmental

Effects of synfuel use

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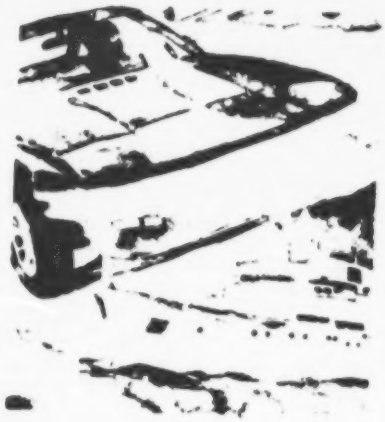

• Most synfuel-related environmental assessment studies have focused on technologies for synfuel production and on emissions from production facilities. On the other hand, little attention has been directed toward an examination of environmental concerns associated with the projected widespread *utilization* of synfuel products. For that reason, EPA sponsored a study to project synfuel production and use during the next 20 years and to rank products from the standpoint of environmental concerns. The objective is to provide input to the EPA efforts of assessing environmental implications of a mature synfuel industry and of large-scale utilization of synfuel products, and planning and prioritizing regulatory and research and development (R&D) programs. The data base used consists of information obtained from major process developers, potential product users, and published literature.

Synfuel technologies likely to be used in commercial plants over the next 20 years are oil shale, coal gasification (low-/medium-Btu and substitute natural gas [SNG]), and coal liquefaction (direct and indirect). Major products of these technologies and their anticipated general uses are indicated in Table 1.

TABLE 1
Major end-use applications of synfuel products

Major synfuel products	Likely major end-use applications
High- and medium-Btu gas	Food, textile, pulp and paper, chemicals, iron and steel industries; residential/commercial heating
Low-Btu gas, LPG	Small boilers, kilns; pelletizing glass; electronics; chemical industries; domestic cooking and heating; automotive
Gasoline	Transportation
Naphtha	Petrochemical industry; solvents; varnish; turpentines
Middle distillates (kerosene, diesel, light fuel oil)	Transportation; gas turbines; residential and commercial heating
Residues	Industrial, utility, and marine fuel; metallurgical oils; roof coatings; wood preservatives, lubricants

Buildup scenarios

The development of a U.S. synfuel industry will be influenced by factors such as the availability of capital to finance the huge construction costs and the willingness of process developers, the private investment sector, and government to accept the technological risks involved in the construction of "first-of-a-kind" facilities. Other important considerations will include U.S. energy policies and prices of domestic and imported natural gas and oil; the availability of skilled manpower, raw material, and equipment for plant construction and operation; and the timely development of the supporting infrastructure necessary for energy product manufacture, distribution, and use. In addition, environmental regulatory requirements, the time and effort required to acquire technical data to support permit applications and obtain approval, and the time and effort required to attain full commercial status for technologies/processes currently under development will have to be taken into account.

Based on different assumed levels of impacts exerted by these factors, several scenarios for the synfuel industry's buildup to the year 2000 were developed and discussed with major synfuel suppliers and users, and industry and government planners. On the basis of these discussions, the scenario illustrated in Figure 1 was selected as the most realistic and was used for environmental analysis. This scenario is consistent with the general consensus among technical experts and potential major suppliers that shale oil is more nearly-cost-competitive and closer to commercialization than are high-Btu gasification or coal liquefaction, and that commercial coal-liquefaction fa-

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cilities will not probably come on-line before the early 1990s.

Synfuel industry buildup and product utilization patterns are analyzed for three time frames: 1980-1987, 1988-1992, and 1993-2000. Table 2 presents the product-by-product estimates of synfuel utilization in the U.S. For comparison, the estimates are also expressed as percentages of the total product consumption. It should be noted that, even though on a national scale, the projected synfuel utilization would account for small fractions of the total product usage, in some regions a very high fraction of currently used products are expected to be replaced by synfuel products. As noted in Table 3, by the year 2000 it is expected that about 36% of all refinery feed and 48% of all middle distillate used in EPA Region 8 would originate from shale oil.

Regions of maximum impact

Table 4 shows EPA regions in which synfuel products would most likely be used, as well as projections for the products' utilization patterns. As noted in the table, except for oil shale in the 1988-1992 and 1993-2000 time frames and for direct coal liquefaction in the 1993-2000 time period, the transportation, distribution, and use of products are expected to be confined to the regions where each synfuel is produced. Consequently, environmental impacts would also be confined primarily to the production regions, except for those caused by the natural transportation of pollutants across regional boundaries. The projections indicate that, up to the year 2000, environmental impacts will be largely limited to EPA Regions 5 and 8 for oil shale; to Regions 4, 6, and 8 for medium-Btu gas; to Regions 3, 4, and 8 for indirect coal liquefaction products; and to Regions 3, 4, and 5 for direct liquefaction products.

Data base

The environmental data currently available on synfuel products are very limited and pertain mainly to certain primary products (for example, crude shale oil or coal liquefaction syncrudes). Very little data are available on many of the secondary synfuel products (for example, methanol and gasoline derived from coal) or on emissions associated with combustion of synfuel products. The combustion tests conducted with certain synfuel products have been aimed primarily at evaluating handling and performance characteristics.

In general, the product/emissions characterization has been in terms of gross properties (for example, ultimate analysis, composition by chemical class, and emissions of smoke and particles during combustion), which by themselves do not provide an adequate basis for assessing environmental significance. The current product characterization data base is a collection of results reported by different investigators who used samples/batches of products obtained from pilot plants operated under varying conditions.

Accordingly, significant inconsistencies exist in the reported results. Environmental analysis is further complicated by a lack of data on analogous petroleum and natural gas products that the synfuel products will replace and that, because of their large-scale and widespread use, have generally come to be viewed by the public as environmentally acceptable.

Comparison with petroleum

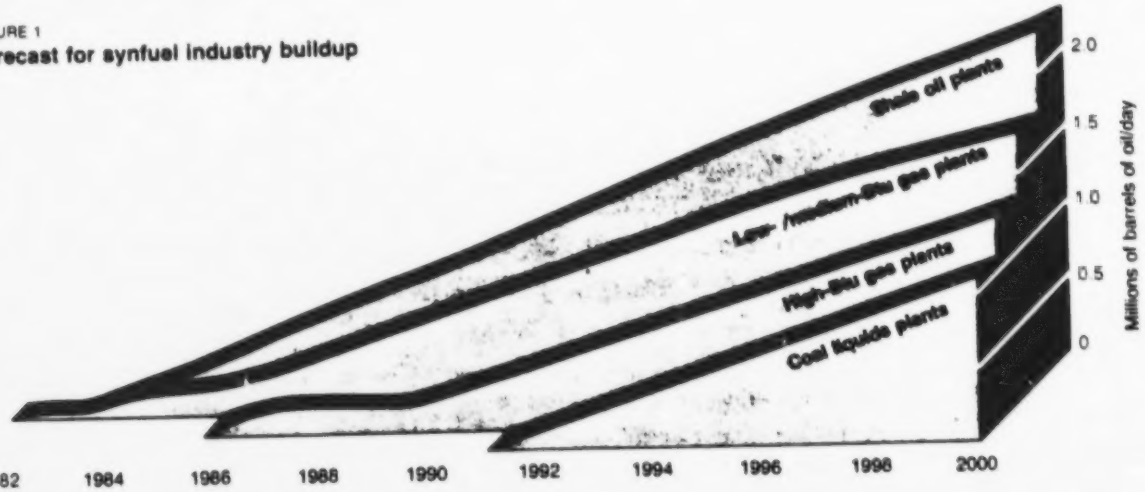
Table 5 identifies the differences in chemical, combustion, and health effects characteristics of synfuel products and their petroleum analogues, based on the reported characterization data. As noted in the table, for the majority of products for which data are reported, these differences primarily relate to the higher content of aromatics and fuel-bound nitrogen (FBN) and the greater emissions of NO_x during combustion.

Although no test data for synfuel products are available, high concentration of aromatics in fuels have been shown to enhance production of polynuclear aromatic hydrocarbons (PAHs) during combustion. However, specific substances that make up the aromatic or FBN fractions in various synfuel products (or their petroleum counterparts) are not known. In the case of fuels, high aromaticity has been implicated in an increase in smoke production; nonetheless, the limited combustion data which are currently available do not indicate that all aromatic synfuels have higher smoke levels.

High FBN content can raise the level of NO_x emissions; the excess NO_x emissions of synfuels are believed to be correctable by combustion modifications. The nitrogen content of synfuels (and the high arsenic content of the crude shale oil) can also be lowered to meet appropriate fuel specifications by employing certain refining processes (for instance, hydrotreating to reduce FBN). Another example of controlling undesirable product characteristics through process control, or in-plant treatment, is the elimination of traces of carbon monoxide and nickel carbonyl in SNG by proper operation of the methanator.

The data in Table 5 identify crude shale oil and liquefaction fuel oils as more hazardous than their petroleum analogues because of greater muta-

FIGURE 1
Forecast for synfuel industry buildup



genic, tumorigenic, and cytotoxic properties. These properties, which are characteristic of high boiling, tarry coal, and petroleum materials, are caused by the presence of substances or classes of substances such as PAHs, hetero- and carbonyl-polycyclic compounds, aromatic amines, and certain inorganics, such as arsenic in crude shale oil.

Environmental concerns relate to occupational exposure, public exposure, and general environmental pollution. The occupational hazards affect workers manufacturing and using the products, as well as personnel involved in facility maintenance and product distribution. Public exposure primarily relates to air pollution resulting from product uses, such as gasoline being burned in automobiles, and hazardous fugitive emissions from storage tanks, product transfer points, leaks, and spills. In the general category of environmental pollution, major contributors include accidental spills, sludges from product storage tanks and spill cleanups, and solid, liquid, and gaseous wastes associated with combustion and combustion-related air pollution control.

Priority ranking

A system was developed to rank synfuel products from the standpoint of environmental concerns, so that those products and areas requiring more immediate, greater regulatory or R&D attention can be identified. The ranking is based on the data presented previously and is subject to the limitations of the existing data base and to the assumptions used in developing the productions and use scenarios. These rankings will most likely change as more data become available, especially for those products for which little or no data are currently available. It should also be noted that this specific approach represents only one of many approaches to rank synfuel products on the basis of environmental concerns.

Two approaches were originally examined for ranking synfuel products: using the limited product characterization data currently available (Table 5), supplemented by engineering judgment where appropriate, and assuming that in the absence of detailed characterization data, and unless the available data indicate otherwise, it would be reasonable to say that a synfuel product would be more hazardous than its petroleum analogue.

Under the first approach, chosen to develop product rankings, a synfuel

TABLE 2
Estimated quantity of synfuel products used in the U.S.

Product	1990–1997		1998–1992		1993–2000	
	Amount (million bbl/day)	Total in U.S., %	Amount (million bbl/day)	Total in U.S., %	Amount (million bbl/day)	Total in U.S., %
Crude shale oil (fuel)	0.0008	0.05	0	0	0	0
Shale oil refinery feed	0.07	0.45	0.41	0.24	0.43	2.4
Shale jet fuel	0.015	1.2	0.09	6.5	0.09	6.8
Shale diesel fuel	0.042	1.2	0.23	6.5	0.23	6.8
Shale residuals	0.007	0.2	0.04	1.3	0.04	1.3
Shale gasoline	0.13	0.2	0.07	0.9	0	0
Medium-Btu gas (coal)	0.09	0.9	0.27	2.8	0.45	4.7
SNG (coal)	0.042	0.4	0.17	1.8	0.25	2.6
Gasifier tars, oils	0.004	0.04	0.01	0.1	0.01	0.1
Gasifier phenol	0.004	0.04	0.01	0.1	0.02	0.2
F-T LPG	0	0	0	0	0	0
F-T medium-Btu gas	0	0	0.01	0.06	0.01	0.1
F-T SNG	0	0	0.03	0.33	0.07	0.7
F-T heavy fuel oil	0	0	0.001	0.02	0.001	0.03
F-T gasoline	0	0	0.02	0.2	0.03	0.4
Mobil M gasoline	0	0	0.05	0.66	0.1	1.3
F-T diesel fuel	0	0	0.002	0.04	0.01	0.1
Fuel methanol	0	0	0.14	1.8	0.23	3.0
SRC-II fuel oil	0	0	0.03	0.3	0.09	1.3
SRC-II naphtha	0	0	0.02	0.2	0.05	0.8
SRC-II LPG	0	0	0.006	0.4	0.02	1.6
EDS fuel oil	0	0	0	0	0.06	1.0
EDS naphtha	0	0	0	0	0.03	0.6
EDS LPG	0	0	0	0	0.01	0.9
H-coal fuel oil	0	0	0	0	0.06	0.4
H-coal naphtha	0	0	0	0	0.03	0.2
H-coal LPG	0	0	0	0	0.01	0.1

Source: TRW forecast in a report to EPA.

product would not necessarily be considered more hazardous because of the mere lack of detailed characterization data. Instead, assignment of a more positive ranking is supported by actual data or is based on strong indications of greater potential hazards. Prioritization of regulatory and R&D activities does not have to await collection of additional data, which should proceed concurrently as a separate effort.

The second approach operates on the premise that if there is any room for error, it is more advisable to err on the safe side. This scenario asserts that, in the absence of detailed characterization data and strong evidence to the contrary, synfuel products—new chemicals from a more "exotic" source—should be considered more hazardous. Nearly all synfuel products would be given a positive ranking, thereby reducing a ranking system's usefulness as a guide in prioritizing regulatory and R&D activities. Acquiring detailed characterization data would be emphasized, while products that are known to present greater environmental concern may not be concentrated on.

TABLE 3

Projected use of shale oil products in EPA Region 8 [a] as percentages of total product quantities used

Product	1980–1987	1988–1992 and 1993–2000
Crude (fuel)	1.3	—
Refinery feed	13.3	35.6
Middle distillate	37.6	48.3
Gasoline	4.8	2.3
Residuals	15.6	6.6

[a] Region of maximum use.

Attribute rating procedure

Table 6 presents the assessment of the environmental concerns for various synfuel products relative to their petroleum analogues on a "barrel-per-barrel" basis. As indicated by the headings in the table, the relative ranking considers potential for exposure, emission, toxic hazard, cost of control, and adequacy of existing regulations. A (+) ranking is assigned to a product if it presents greater concern than the petroleum analogue; a ranking of (0) indicates similar or lower levels of concern.

Table 7 presents the results of synfuel products ranking. The products are ranked into three groups: 1, those eliciting the most concern; 2, those indicating modest concern; and 3, those generating a low level of concern at the present time. As noted in the table, from 1980 to 1987, the synfuel products of concern will primarily be shale oil products, medium-Btu gas, and SNG. Shale oil refinery feed will elicit the most regulatory attention; other shale oil products and medium-Btu gas will elicit modest concern; SNG will require a low level of attention.

In the 1988–1992 period, when products from the SRC-II (solvent-refined coal) and Fischer-Tropsch (F-T) processes will also be marketed, the products eliciting the most concern will be shale oil refinery feed, SRC-II fuel oil, and gasifier tars and oils. F-T products and LPG from SRC-II are ranked as low-priority products during 1988–1992. During the 1993–2000 time frame, shale oil refinery feed, medium-Btu gas, gasifier tars and oil, and liquefaction fuel oils are given "1"

TABLE 4

Estimated utilization patterns for synfuel products in EPA regions affected [a, b]

Synfuel	Time frame	Production	Refining	Utilization/products
Shale oil	1980–1987	8	8	8: Mid-distillate (57), gasoline (13), residuals (7)
	1988–1992	8 (410)	8 (210)	8: Mid-distillate (155), gasoline (36), residuals (19)
	1993–2000		5 (200)	5: Residuals (18)
				5 & 7: Mid-distillate (148), gasoline (34)
Low- /medium-Btu coal gas	1980[c]–1987	4 (30)	—	4: Gas (30)[d]
		6 (30)	—	6: Gas (30), tars/oils (0.98–1.9), phenols (0.15–0.30), naphtha (0.25–0.72)
		8 (30)	—	8: Gas (30), tars/oils (0.98–1.9), phenols (0.15–0.30), naphtha (0.25–0.72)
Indirect coal-liquefaction products	1988–1993	8 (100)	8 (100)	8: Gasoline (64.5), mid-distillates (2.5), residuals (0.7), SNG (32.6), LPG (0.1), tars/oils and phenols
	1993–2000	8 (200)	8 (200)	8: Gasoline (129), SNG (65.2), diesel fuel (5.0), residuals (1.4), LPG (0.2), tars/oils and phenols
		4 (150)	4 (150)	4: Gasoline (150)
		3 (300)	3 (300)	3: Gasoline (300)
Direct coal-liquefaction products	1988–1992	5 (50)	5 (50)	5: Naphtha (15.4), mid-distillate (18.7), residuals (10), LPG (5.9)
	1993–2000	3 (50)	3 (50)	3: Naphtha (15.4), mid-distillate (18.7), residuals (10), LPG (4.5)
		4 (100)	4 (100)	6: LPG (10.6)
		5 (200)	5 (200)	4: Mid-distillate (37.4), naphtha (30.8), residuals (20.0), LPG (9.0)
				5: Naphtha (61.6), mid-distillate (74.8), residuals (40.0), LPG (20.2)

[a] The EPA regions comprise the following states: 1 = Maine, N.H., Vt., Mass., R.I., Conn.; 2 = N.J., N.Y., P.R., V.I.; 3 = D.C., Del., Md., Pa., Va., W.Va.; 4 = Ala., Fla., Ga., Ky., Miss., N.C., S.C., Tenn.; 5 = Ill., Ind., Mich., Minn., Ohio, Wis.; 6 = Ark., La., N.M., Okla., Tex.; 7 = Iowa, Kans., Mo., Nebr.; 8 = Colo., Mont., N.D., S.D., Utah, Wyo.; 9 = Ariz., Hawaii, Nev., Calif.; 10 = Alaska, Idaho, Ore., Wash.

[b] Numbers shown in parentheses are product quantities in 10^3 bbl/day oil equivalents.

[c] Production and utilization patterns for 1988–1992 and 1993–2000 are the same as shown.

[d] Use of Texaco process, which does not generate tars, oils and phenols, is anticipated.

TABLE 5

Reported known differences in chemical, combustion, and health effects characteristics of synfuel products and their petroleum analogues

Product	Chemical characteristics	Combustion characteristics	Health effects characteristics
Shale oil			
Crude	Higher aromatics, FBN, As, Hg, Mn	Higher emissions of NO_x, particles, and (possibly) certain trace elements	More mutagenic, tumorigenic, cytotoxic
Gasoline	Higher aromatics	Slightly higher NO_x and smoke emissions	—
Jet fuels	Higher aromatics	Slightly higher NO_x and smoke emissions	Eye/skin irritation, skin sensitization same as for petroleum fuel
DFM	Higher aromatics	Slightly higher NO_x and smoke emissions	Eye/skin irritation, skin sensitization same as for petroleum fuel
Residuals	Higher aromatics	—	—
Direct liquefaction			
Syncrude (H-coal, SRC-II, EDS)	Higher aromatics and nitrogen	—	—
SRC-II fuel oil	Higher aromatics and nitrogen	Higher NO_x emissions	Middle distillates: nonmutagenic; cytotoxicity similar to but toxicity greater than No. 2 diesel fuel; burns skin. Heavy distillate: considerable skin carcinogenicity, cytotoxicity, mutagenicity, and cell transformation
H-coal fuel oil	Higher nitrogen content	Higher NO_x emissions	Severely hydrotreated: nonmutagenic, nontumorigenic, low cytotoxicity
EDS fuel oil	—	Higher NO_x emissions	—
SRC-II naphtha	Higher nitrogen, aromatics	—	Nonmutagenic, extremely low tumorigenicity, cytotoxicity, and fetotoxicity
H-coal naphtha	Higher nitrogen, aromatics	—	Nonmutagenic
EDS naphtha	Higher nitrogen, aromatics	—	—
SRC-II gasoline	Higher aromatics	—	—
H-coal gasoline	Higher aromatics	—	—
EDS gasoline	Higher aromatics	—	—
Indirect liquefaction			
F-T gasoline	Lower aromatics; N and S nil	—	Noncarcinogenic
F-T by-product chemical	—	NA[a]	—
Mobil-M gasoline	(Gross characteristics similar to petroleum gasoline)	—	—
Methanol	—	Higher aldehyde emissions	Affects optic nerve
Gasification			
SNG	Traces of metal carbonyls and higher CO	—	—
Low- /medium-Btu gas	(Composition varies with coal type and gasifier design/ operation	(Emissions of a wide range of trace and minor elements and heterocyclic organics)	Nonmutagenic, moderately cytotoxic
Gasifier tars, oils, phenols	(Composition varies with coal and gasifier types; highly aromatic materials)	—	—

[a] NA = not applicable.

rankings.

The rankings generally indicate that the greatest level of environmental concern and regulatory requirements are for shale oil refinery feed and coal liquids. These liquids have been demonstrated to be more hazardous than petroleum crude and fuel oils (a major factor in assigning a "1" ranking). This and the fact that shale oil products are expected to be the first synfuels to enter the market on a large scale are the major factors that "flag" near-term environmental concerns for shale oil products in general, and shale oil fuel and refinery feed in particular.

Data limitations

As noted previously, there are a number of major gaps in the existing data base that preclude accurate analysis of the environmental concerns associated with future large-scale utilization of synfuel products in the U.S. These gaps are: present uncertainties regarding the size of the industry, specific synfuel technologies that will be used and product slates that will be produced, locations of production facilities and product distribution systems, and the specific areas of synfuel use; and lack of adequate characterization data on synfuel products and on the analogous petroleum products that they will partially or totally replace. The first category of data limitations has an impact on the regional environmental implications and synfuel production scenarios and market analyses that were developed, whereas the second category of limitations introduces uncertainties in the estimated characteristics of synfuel products and the analysis of environmental concerns. Both types of data limitations affect the regional environmental implications and the ranking of the synfuel products.

At present, the first category of data gaps can only be partially filled, perhaps through engineering and eco-

TABLE 6

Relative assessment of environmental hazards [a]

Product	Exposure [b]		Emission factor [b]		Toxic hazard [b]		Cost of control [b]	Adequacy of existing regulations [c]			
	Transport and storage	End use	Transport and storage	End use	Transport and storage	End use		CAA [d]	CWA [e]	RCRA [f]	TSCA [g]
Crude shale oil (fuel)	+	0	0	+	+	+	+	+	+	+	0
Shale oil refinery feed	+	0	0	0	+	+	0	0	+	+	0
Shale jet fuel	0	0	0	+	0	+	+	+	0	+	0
Shale diesel fuel	0	0	0	+	0	+	+	+	0	+	0
Shale residuals	0	0	0	+	+	+	+	+	+	+	0
Shale gasoline	0	0	0	+	0	+	+	+	0	+	0
Low- /medium-Btu gas (coal)	0	0	0	+	+	+	+	+	0	+	0
SNG (coal)	0	0	0	0	0	0	0	0	0	0	0
Gasifier tars and oils	0	0	0	+	+	+	+	+	+	+	0
Gasifier phenol	0	0	0	+	+	+	0	0	0	0	0
F-T LPG	0	0	0	0	0	0	0	0	0	0	0
F-T medium-Btu gas	0	0	0	0	0	0	0	0	0	0	0
F-T SNG	0	0	0	0	0	0	+	0	0	+	0
F-T heavy fuel oil	0	0	0	0	0	0	0	0	0	+	0
F-T gasoline	0	0	0	0	0	0	0	0	0	+	0
Mobil-M gasoline	0	0	0	0	0	0	0	0	0	+	0
F-T diesel fuel	0	0	0	0	0	0	0	0	0	+	0
Fuel methanol	0	0	0	0	0	0	0	0	0	0	0
SRC-II fuel oil	+	0	0	+	+	+	+	+	+	+	0
SRC-II naphtha	0	0	0	0	+	+	0	0	+	+	0
SRC-II LPG	0	0	0	0	0	0	0	0	0	0	0
EDS fuel oil	+	0	0	+	+	+	+	+	+	+	0
EDS naphtha	0	0	0	0	+	+	0	0	+	+	0
EDS LPG	0	0	0	0	0	0	0	0	0	0	0
H-coal fuel oil	+	0	0	+	+	+	+	+	+	+	0
H-coal naphtha	0	0	0	0	+	+	0	0	+	+	0
H-coal LPG	0	0	0	0	0	0	0	0	0	0	0

[a] Associated with synfuel products and petroleum analogues.
[b] 0 = similar, or lower hazard than petroleum analogue. + = greater hazard than petroleum analogue.
[c] 0 = regulations are adequate. + = regulations are inadequate.
[d] Clean Air Act.
[e] Clean Water Act.
[f] Resource Conservation and Recovery Act.
[g] Toxic Substances Control Act.

Reported or estimated environmentally significant characteristics of synfuel products relative to those of their petroleum analogues, based on exposure potential, combustive and evaporative emissions, toxic hazards, cost of control, and the extent of regulatory protections under key existing environmental legislations. Products for which the environmental risks and control needs are greater, and for which less regulatory protections are anticipated, are given a higher ranking.

The estimated quantity of products used, both in absolute terms and as percentages of the total (synfuel and petroleum) used nationwide (Table 3) and regionally. The greater the amount of the product used and the percentage of usage, the greater the potential for presenting environmental hazards, and hence a higher positive ranking.

Considerable scientific and engineering judgment. Because of the lack of a solid data base, heavy reliance was placed on the professional judgment of experts most familiar with the domestic energy supply and demand picture, synfuel production/refining technologies, expected environmental characteristics of synfuel products, applicable controls, and regulatory needs.

TABLE 7

Priority ranking of synfuel products from the standpoint of environmental concerns[a]

Product	1980–1987	1988–1992	1993–2000
Crude shale oil (fuel)	2	—	—
Shale oil refinery feed	1	1	1
Shale jet fuel	2	2	2
Shale diesel fuel	2	2	2
Shale residuals	2	2	2
Shale gasoline	2	2	2
Medium-Btu gas (coal)	2	2	1
SNG (coal)	3	3	3
Gasifier tars, oils	—	1	1
Gasifier phenol	2	2	2
F-T LPG	—	3	3
F-T medium-Btu gas	—	3	3
F-T SNG	—	3	3
F-T heavy fuel oil	—	3	3
F-T gasoline	—	3	3
Mobil-M gasoline	—	3	3
F-T diesel fuel	—	3	3
Fuel methanol	—	3	3
SRC-II fuel oil	—	1	1
SRC-II naphtha	—	2	2
SRC-II LPG	—	3	2
EDS fuel oil	—	—	1
EDS naphtha	—	—	2
EDS LPG	—	—	3
H-coal fuel oil	—	—	1
H-coal naphtha	—	—	2
H-coal LPG	—	—	3

[a] Degree of concern: 1 = most, 2 = modest, 3 = low; (—) indicates product not produced or not used as indicated.

nomic analyses to determine optimum product slates. Many of the gaps in the second category, however, can and should be filled through testing and evaluation of synfuel products obtained from U.S. pilot plants and from commercial facilities abroad.

A number of chemical and biological/ecological testing programs that are expected to improve substantially the quality of the existing data base on synfuel products are currently under way. These programs are conducted and sponsored largely by DOE and EPA. In addition, a number of product performance testing efforts that may provide excellent opportunities for cost-effective collection of end-use environmental data, are under way or are planned. These programs include testing shale-derived jet fuels in commercial and military aircraft engines (U.S. Air Force, Wright-Patterson AFB; U.S. Navy), standing diesel engine tests with SRC-II and shale oil diesel fuels (DOE Bartlesville Energy Research Center), testing a spectrum of synfuel gasoline and jet fuels in ground and air transportation vehicles (U.S. Department of Transportation), and evaluating the use of synthetic fuels in utility boilers (Electric Power Research Institute).

Recommendations

Several recommendations grew out of the study:

A more systematic approach to product characterization and testing. Much of the currently available synfuel product characterization and testing data are fragmentary and cannot be correlated. The results generally do not cover all parameters of environmental interest; rather, they have been obtained in "isolated" studies which used samples from different batches of products. Better coordination among various ongoing and planned studies (perhaps through establishing a "test tracking" system that would promote exchanges of information developed by various studies) is recommended to avoid duplication of effort and to ensure generation of appropriate environmental data in a most cost-effective manner.

Collection of environmental data in conjunction with planned performance testing programs. Several synfuel product performance testing efforts are being planned by various government agencies. It is most appropriate and timely to review these programs and to take full advantage of opportunities for simultaneous collection of environmental data. These data, which can be correlated with product performance, in conjunction with a sys-

tematic product characterization effort, can provide valuable, timely inputs to the evolution of the synfuel industry and would ensure that:

- environmental considerations are included in the selection of processes, equipment, and product slates for commercial facilities
- the drafting of specifications for synfuel products, new-source performance standards for synfuel plants, and emissions standards for facilities using synfuel products are based on the best available technical data.

Consideration of end-use environmental implications in the selection of the product slates and in the development of the synfuel industry. Some synfuel processes and subsequent refining operations can be altered or added to include products that could be used in end-use applications with potentially fewer and more controllable environmental impacts. Studies should be undertaken to define the engineering and economics of such alterations and additions. In this connection, better coordination and exchange of technical data should be promoted among process developers, regulatory agencies, and potential users and planners to ensure that environmental considerations are incorporated in the development and marketing of synfuel products.

Compilation of characterization/performance data on analogous petroleum products. Very little data are available (or if available, have not been published) on potential pollutants or on toxicological and ecological properties of many of the petroleum products to provide a baseline for assessing the safety of synfuel products. It is recommended that the potential sources of data on petroleum products be contacted in an effort to compile all available data and identify data gaps. It is also recommended that the synfuel product testing and characterization efforts include parallel testing of petroleum-derived analogues.

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